# XXII. *Additional Observations on making a Thermometer for measuring the higher Degrees of Heat.* By Mr. Josiah Wedgwood, *F. R. S. and Potter to Her Majesty.*

Read June 22, 1786.

MY thermometer for meaſuring the higher degrees of heat having been honoured with the notice of this illuſtrious Society, I now requeſt a further indulgence for a few more obſervations on the ſame ſubject.

In my firſt Paper * I communicated every thing that experience had then taught me, reſpecting both the conſtruction and uſe of this thermometer; but more extenſive practice has ſince convinced me, that other managements and precautions are neceſſary, in order to bring it to the perfection it is capable of receiving: for pieces made of the ſame clay, and exactly of the ſame dimenſions, have been found to differ in the degree of their diminution by fire, in conſequence of ſome circumſtances in the mode of their formation, at that time unheeded, and very difficult to be developed.

Of the two ways propoſed for forming them, the mould and the preſs, the former was made choice of, as being, for general uſe, the moſt commodious. The ſoft clay was preſſed into a ſquare mould with the fingers; and the pieces, when dry, were pared down on two oppoſite ſides, by means of a

* Philoſophical Tranſactions, Vol. LXXII.

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paring gage made for that purpoſe, ſo as to paſs exactly to 0° at the entrance of the converging canal of the meaſuring gage.

But the pieces thus formed have been found liable, in paſſing through ſtrong fire, to receive a little alteration in their figure, which produces an uncertainty with reſpect to their ſubſequent meaſurement: the two ſides, inſtead of continuing flat, become concave; the edges, both at top and bottom, projecting beyond the middle part, ſometimes very conſiderably, as at *a* and *b*, fig. 1, (Tab. XIV.) where AB repreſents a perpendicular ſection of an unburnt piece, and *a b* a like ſection of the ſame piece after it has undergone a heat of 160 degrees. This irregularity in the form, which is ſenſible only after paſſing through the high degrees of fire, was obſerved in ſome of the early experiments, but was not then looked upon as being productive of any error.

On more attentively examining this matter, it appeared, that when the clay is preſſed into a mould, the ſurface in contact with the mould acquires a more compact texture than the inner part of the maſs;—that this compactneſs reſtrains, in ſome degree, its diminution in the fire;—and therefore, that when this ſurface, or leſs diminiſhable cruſt, is pared off from the two ſides only, the piece may be conſidered as having its upper and lower ſtrata (AA and BB, fig. 1.) compoſed of a leſs diminiſhable matter than the intermediate part, the neceſſary conſequence of which ſtructure will be ſuch a figure as we find the pieces to aſſume; for if any ſtratum in the maſs ſhrinks leſs than the reſt, the extremities of that ſtratum muſt be left proportionably prominent. That this was the true cauſe of the inequality, I was convinced by firing ſome pieces *unadjuſted*, with all their ſurfaces entire, as they came from the mould; for theſe pieces, after paſſing through the ſame ſtrong

fires with the preceding, continued flat, with the angles regularly ſharp, and without the leaſt ſenſible prominence in any part.

Some of the moulds, employed for this uſe, were made of plaſter, a material more convenient for the workman than metal, as the pieces part more freely from it, but which contributed greatly to increaſe the above-mentioned irregularity: for the plaſter, by abſorbing a portion of the water from the clay contiguous to it, renders the ſurface at the ſame time, even at the inſtant of contact, much more *conſiſtent*, and conſequently more difficult to preſs into the angles of the mould; ſo that the outſides of theſe pieces were not only more *compreſſed*, but formed of clay of a different *temper* from the inner parts, being much drier or firmer; a circumſtance which, as will appear hereafter, reſtrains ſtill more their diminution in the fire.

The moulds were therefore laid aſide, and the preſs adopted in their ſtead; for as the ſoft clay, preſſed in a cylindrical veſſel, gives way and eſcapes through an aperture made for that purpoſe (by which means it is formed into long rods), the ſides of the piece cannot be ſuppoſed to receive ſo great a degree of compreſſure againſt the ſides of the aperture through which it is *delivered* in this operation, as it does againſt the ſides of the mould, by which it is *confined* till every part has born a preſſure ſufficient to force the clay into every angle, which is much greater than even a workman would imagine till he comes to try the experiment himſelf.

But with this change ſome new difficulties aroſe; for pieces preſſed through the ſame aperture, and from the ſame preſſ-ful of clay, and adjuſted, when dry, to the ſame point in the gage, were found, after paſſing together through the ſame

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ſtrong fires, to differ in their dimenſions from one another, in ſome inſtances more than any of the preceding.

Having hitherto paid no particular attention myſelf to the mere manual labour of preſſing the clay, I determined, upon this event, to go through that and every other operation, however ſimple and ſeemingly inſignificant, with my own hands. In doing this I obſerved, that the power neceſſary for forcing the clay through an aperture which bore but a ſmall proportion to the diameter of the maſs of clay in the preſs, was ſo great as to ſqueeze out, along with the clay that firſt paſſed through, a conſiderable portion of the water that belonged to the reſt. From this over-proportion of water in the compoſition of the firſt pieces they were ſoft and ſpongy, and the ſucceeding ones more and more compact, till at length the clay proved ſo ſtiff as ſcarcely to be forced through at all.

Clay, containing different proportions of water, is well known to diminiſh differently in drying; but it was not imagined that, when dry, there would be any difference in its ſubſequent diminutions by fire. Experiments however, multiplied in a variety of circumſtances, ſhewed deciſively, what the pieces formed in the mould had given grounds to ſuſpect, that thoſe formed of the ſofteſt clay, and which had undergone the leaſt preſſure, diminiſhed moſt in burning; and that the diminution is uniformly leſs and leſs, in proportion to the greater degree of preſſure or compactneſs.

The knowledge of the cauſe of the irregularity ſuggeſted a remedy. I leſſened the width of the preſs very much, ſo as to bring the diameter of the maſs of clay, and that of the aperture through which it is delivered, to a nearer proportion with one another. A much leſs degree of force being now ſufficient, the pieces, or rods, were proportionably more uniform, though

though there was ſtill a ſenſible difference, in conſiſtence, between thoſe which were firſt and laſt preſſed out from the ſame maſs of clay. The intermediate ones, within a certain diſtance from the two extremes, correſponded very nearly with one another; ſo that by rejecting a ſufficient number of the firſt and laſt, and uſing the *intermediate ones only*, the inequality may be conſidered as almoſt annihilated.

I nevertheleſs ſtill found that, in ſtrong fire, the edges became a little prominent, though not ſo much as before. I was aware that theſe pieces muſt partake, in ſome degree, of the imperfection of thoſe made in the mould; having their ſurfaces rendered, by their friction againſt the ſides of the aperture, more compact than the inner part. But I ſuſpected that ſomething might depend alſo upon the *form*, and accordingly made many trials for aſcertaining the form that might be leaſt liable to this irregularity: the angles only were bevilled off, the ſides were rounded, the pieces were rounded all over, made of ovals and other curves, and both the longeſt and ſhorteſt dimenſions were uſed as the extent to be meaſured: the general reſult was, that the nearer they came to a circular figure, the leſs inequality they contracted in the fire, and by making them entirely circular, the imperfection appeared to be obviated altogether; cylindric pieces bearing the ſtrongeſt fires without the leaſt appearance of prominence or inequality in any part of their ſurface. I have therefore choſen this laſt form, leaving only one narrow flat ſide (*a b*, fig. 2.) as a bottom for the pieces to reſt upon, and to diſtinguiſh the poſition in which they are to be meaſured in the gage.

I have endeavoured at the ſame time to obviate whatever inaccuracy the inequality of compactneſs may be capable of producing, by ſo adjuſting the aperture through which the

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rods are preſſed, and on which their figure and dimenſions depend, as to ſuperſede the uſe of the paring gage altogether; that the whole ſurface may remain of the ſame uniform compactneſs which it received in the preſs. And as it is ſcarcely practicable, in any mode of forming ſoft clay, to have all the pieces preciſely of the ſame dimenſions after drying, I do not reject thoſe which come within two or three degrees of the ſtandard, but, inſtead of injuring the ſurface by paring or rubbing, I mark on the ends the degrees which they reſpectively exceed or fall ſhort; which degrees are accordingly to be ſubſtracted, or added, in all obſervations of heat made with thoſe pieces. Strictly ſpeaking, an allowance ought to be made alſo for the proportional diminution upon this exceſs or deficiency itſelf; but the allowance for three degrees would not, at the melting heats of copper, ſilver, or gold, amount to more than a ſeventh part of a degree; and at the extreme point of heat that I have been able to attain, when the piece has diminiſhed $\frac{160}{600}$, or nearly one-fourth of its whole thickneſs, it comes only to four-fifths of a degree.

It may be proper to take notice of an irregularity in the *apparent* diminutions of the pieces, which was ſometimes obſerved to happen from another cauſe, their bending a little in ſtrong fire, ſo as to be prevented from going ſo far in the gage as they would have done if they had continued perfectly ſtraight. But as this takes place only in pieces of conſiderable length, and as they derive no advantage of any kind from that length, the remedy is too obvious to need being here mentioned.

Another fallacious appearance aroſe, not from any imperfection in the pieces themſelves, but from a deception with reſpect to the heat in which the compariſon of them had been

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made. In one period of the courſe of my experiments, I employed, for firing them, a ſmall, ſhallow, cylindrical veſſel (fig. 3.) ſetting the pieces on end, cloſe together, on its bottom, and placing it in the middle of the fuel, in a common air-furnace, with care to keep the fire as equal all round it as poſſible. It was expected, that all the pieces would receive an equal heat; and as they were found, after the operation, to differ in their dimenſions, ſometimes conſiderably, from one another, theſe differences proved a ſource of much perplexity, till it was diſcovered that the pieces had really undergone unequal degrees of heat.

In the paper on the compariſon of this thermometer with FAHRENHEIT's *, I have taken notice of the great difficulty of obtaining, in ſmall furnaces, a perfectly equal heat, even through the extent occupied by a few of theſe little pieces: and how different the heat may be in different parts of one veſſel, we may be ſatisfied by an eaſy experiment, *viz.* ſetting a cylindrical rod of clay, of the length of eight or ten inches, upright in the middle of a crucible, and urging it with ſtrong fire in a common ſmall furnace; the rod will be found very differently diminiſhed at different parts of its height; and if its height be ſufficient to reach ſome way above the fuel, nearly the whole range of the thermometric ſcale may be produced in one rod; an ocular proof, not only of the diverſity of heat within a ſmall compaſs, but likewiſe of the *peculiar* ſenſibility of this thermometer, every *part* of the maſs expreſſing diſtinctly the degree of heat which it has itſelf felt. It will be proper, in this experiment, to have a tube fixed in the bottom of the crucible, for keeping the rod ſteady, as at fig. 4. By this means the heat of my air-furnace renders a

* Philoſophical Tranſactions, vol. LXXIV.

rod of the thermometric clay tapering, from about four parts in diameter at top to three at bottom, which are nearly the proportions between the width of the piece when unburnt, or but juſt ignited, and when it has ſuffered a heat of 160 degrees.

To the foregoing ſources of inequality in the pieces, one more may be added, ſmall cavities, or air-bubbles accidentally incloſed, which ſometimes happened in the earlier experiments. In order to prevent theſe, particular attention is now paid by the workmen to what we call *handing* or *ſlapping* the clay, an operation by which its different parts are intermixed, and the maſs rendered of an uniform temper throughout. The workman takes a lump of the clay in his hands, perhaps of two pounds weight, and, breaking it in two in the middle, lays one part upon the other, and preſſes them flat again, repeating this forty or fifty times, or perhaps oftener. Now, conſidering the pieces at firſt as two diſſimilar maſſes, with any number of air-bubbles incloſed; each of theſe pieces being by the firſt doubling divided into two, by the next into four, by the third into eight, and ſo on in geometrical progreſſion, each of the original maſſes will be divided by the fiftieth repetition into upwards of eleven thouſand millions of millions of inviſible laminæ:—inviſible, becauſe the lump of clay would, long before the laſt doubling, be of one uniform colour, though at firſt one-half of it had been black, and the other white. If therefore no air be incloſed between the pieces at the times of their being put together in this proceſs, all the air which might have been in the maſs before would certainly be driven out; and, to avoid as much as poſſible the introduction of any freſh portions of air, the two ſeparated pieces are each time made ſmooth, and a little convex, on the ſurfaces that are to be brought together.

By due attention to the circumſtances above ſtated, any ſingle quantity of clay may be made up into thermometer-pieces, that ſhall differ very little, if any thing at all, from one another.

But a new difficulty now aroſe, more embarraſſing than any of the former; that of procuring freſh ſupplies of clay, of the ſame thermometric quality with the firſt. The quantity of the clay which, after trial of many others, I had made choice of, was ſmall; but the particular ſpot it was taken from being known, and having purchaſed the little eſtate in which it was raiſed, I had not a doubt of obtaining more of the ſame when it ſhould be wanted: for clays in general, when raiſed from an equal depth, in the ſame ſtratum, and near the ſame place, are found to poſſeſs the ſame properties, with reſpect to ductility in the hands of the workman, a diſpoſition to aſſume by fire a porcelain or vitreous texture, ſingly or in compoſition, and all other qualities relative to their uſe in pottery. In this, however, I was deceived; for when a freſh ſupply was wanted, to complete my experiments, though I had ſome taken from a pit joining to the firſt, and at the ſame depth, it was found to diminiſh differently from the former parcel. I then had ſome raiſed from different parts of the ſame field and bed, and at different depths; and in various other places in Cornwall, from the ſpot where this ſpecies of clay is firſt met with to the Land's-End; but all theſe clays differed ſo much from the firſt in the quantity of their diminution by fire, and moſt of them likewiſe from each other, that I deſpaired of being ever able to find one that would correſpond with it, or any natural clays that could be obtained twice of exactly the ſame *thermometric* properties, how ſimilar ſoever in other reſpects.

Upon a review of the numerous compariſons which I have made of theſe new clays, in different degrees of heat, from the

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commencement of rednefs up to intenfe fire, the moft ftriking differences of the greateft part of them from the old feemed to originate in the lower ftages of heat; and of thofe which were got from the neighbourhood of the old, the variations from it in the higher ftages feemed, for the moft part, to be only confequences of thofe differences in the lower ones.

I have mentioned, in the firft Paper, that the original thermometer-pieces had their bulk enlarged a little on the approach of ignition; but that by the time they became vifibly red-hot throughout, they are reduced to their former dimenfions again; and at this moment the thermometric diminution begins. The new clays had their bulk enlarged in a much greater proportion, and the enlargement was of much longer continuance: fome of them required a heat of 15 degrees to deftroy the increafe which ignition had produced in their bulk, and bring them back to their original dimenfions: after this period, moft of them diminifhed pretty regularly, and uniformly with the old, being nearly fo many degrees behind it, in all the fucceeding ftages of heat, as they required to bring them back from the enlarged ftate.

I have mentioned alfo, in my former paper, that a quantity of air is extricated from the clay, moft rapidly at the period in which the augmentation of bulk takes place; and that the augmentation was probably owing to this air forcing the particles of the clay a little afunder, previous to the inftant of its efcape. It was therefore prefumed, that the greater extenfion of thefe new clays might be owing, either to a greater quantity, or ftronger adhefion, of this combined air: and as clay, kept moift for a length of time, in certain circumftances, undergoes a procefs feemingly analogous to fermentation,

tion, it was hoped that, by ſuch a proceſs, part of its combined air might be detached.

But experiments made on this idea have proved, that theſe clays, kept moiſt for a twelvemonth,—kept for a conſiderable length of time in a heat juſt below viſible redneſs,—boiled in water for many hours,—alternately, and repeatedly, moiſtened and dried,—ſuffer no alteration in their thermometric properties, and continue to differ from the ſtandard clay juſt as much as they did at firſt.

Some of theſe new clays differed from the old in a property ſtill more eſſential, and by which I was much more diſconcerted; for though they continued diminiſhing with tolerable regularity, keeping only ſome degrees behind it, up to a certain period of heat, about that in which caſt iron melts; yet many of the pieces, urged with a heat known to be greater than that, were found not to be diminiſhed ſo much as thoſe which had ſuffered only that lower heat. Further experiments ſhewed, that, after diminiſhing to a certain point, they begin, upon an increaſe of the heat beyond that point, to ſwell again: and as this effect is conſtant in certain clays, and begins earlieſt in thoſe which are moſt vitreſcible, and as clays are found to ſwell upon the approach of vitrification, I look upon this ſecond enlargement of bulk, however inconſiderable, as a ſure indication of the clay or compoſition having gone beyond the true porcelain ſtate, and of a diſpoſition taking place towards vitrification; which ſtage is always, ſo far as my experience reaches, attended with a new extrication of air; and in ſome inſtances, this air being unable to make its eſcape from the tenacious maſs that envelopes it, the burnt clay is thereby ſo much increaſed in bulk as to ſwim on water like very light wood. The degree of heat therefore, at which this enlargement

ment begins, may be conſidered as a criterion of the degree of vitreſcibility of the compoſition; which points out a new uſe of this thermometer, enabling us to aſcertain the *degree of vitreſcibility* of bodies that cannot actually be vitrified by any fires which our furnaces are capable of producing.

All my reſearches among the natural clays proving fruitleſs, and the experiments having ſhewn that all thoſe, which could ſufficiently reſiſt vitrification, diminiſhed *too little* in the fire, I endeavoured to find a body poſſeſſed of the oppoſite property, that is, diminiſhing *too much*, and, by a mixture of theſe two, to produce the *medium* diminution required. As I could not find any natural ſubſtance poſſeſſed of that property, which would not at the ſame time render the compound too vitreſcible, I was obliged to have recourſe to ſome artificial preparation; and as the earth of alum is the pure argillaceous earth, to which all clays owe their property of diminution in the fire, poſſeſſing that property in a greater or leſs degree according to the quantity of alum earth in their compoſition, I mixed ſome of this earth with the clay, and found it to anſwer my wiſhes completely, both in procuring the neceſſary degree of diminution, and increaſing its unvitreſcibility. So little is this compound diſpoſed to vitrification, that the greateſt heat I could give it, that of 160°, did not even bring it to a porcelain texture, but left it ſtill bibulous; and as it does not arrive at the *porcelain* ſtate in this fire, there can be no danger of its approaching too near to the *vitreſcent* in any heat that we can produce in a furnace.

In order to obtain the exact medium required, I took one of the beſt of the clays I had procured from Cornwall, and mixed it with different proportions of the alum earth, till the compoſition was found, on repeated trials, to agree with the original

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in all degrees of heat. This coincidence was not indeed eſſential; but as many degrees of heat were already before the public, meaſured by thermometer-pieces made of the firſt clay, and as the correſpondence of the firſt with FAHRENHEIT's ſcale had likewiſe been in ſome meaſure aſcertained, it was deſirable that the ſame degrees of heat ſhould continue to be expreſſed by the ſame numbers.

The alum earth is prepared for this purpoſe by diſſolving the alum in water, precipitating with a ſolution of fixed alkali, and waſhing the earth repeatedly with large quantities of boiling water: when the earth has ſettled, the water above it is let off by cocks in the ſides of the hogſheads; and when the veſſels are filled up with freſh water, care is taken to ſtir up the earth from the bottom, and mix it thoroughly with the liquor. I find it moſt convenient to uſe the earth undried, in its gelatinous ſtate, as in this ſtate it unites eaſily and perfectly with the clay; whereas, when the alum earth has concreted into dry maſſes, great labour is neceſſary to mix them uniformly together.

I have tried ſeveral different parcels of Engliſh alum, from the ſame and from different manufactories, and found no material difference in the quantity of earth it contains*. Nor indeed would it be of any conſeqence if there was a difference in this reſpect, as the proportion of alum earth neceſſary for

* A difference in the quantity of earth *may* ariſe from different proportions of GLAUBER's ſalt and vitriolated tartar, of which I have found quantities very conſiderable, but nearly alike, in all the Engliſh alum I have examined. Theſe ſalts are doubtleſs formed by the kelp aſhes employed in the preparation of the alum. They are diſcovered by calcining the dried alum with charcoal powder, which decompoſes the alum only, leaving the other two ſalts intermixed with the alum earth, from whence they may be extracted by water.

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different clays, and even for different parcels of the ſame clay, can only be aſcertained by repeated trials, adding ſucceſſive quantities of the earth till the deſired effect is found to be produced. Ten hundred weight of the Cornwall porcelain clay which I have now in uſe required all the earth that was afforded by five hundred weight of alum.

It is material in this place to obſerve, that the earth of alum is extremely tenacious of water, inſomuch that, though apparently dry, the water and air amount to near as much as the pure earth, and are not to be completely driven out without a full red heat. When divided by the admixture of other earthy bodies, it parts with its water eaſier indeed than before; but a mixture containing ſo much of it as the thermometric compoſition does, is far more retentive of water than common clay, and requires to be kept for ſome time in a heat equal to that of boiling water, before it is to be conſidered as dry, that is, before the adjuſtment of the pieces in the gage. If they are adjuſted when only apparently dry, or of ſuch a degree of dryneſs as they can be brought to by a heat that the hand can bear, the heat of boiling water will diminiſh them two or three degrees; and the greateſt part of what they have thus been deprived of, they gradually recover again on being expoſed to the atmoſphere, ſo that the adjuſtment muſt be made immediately after the boiling heat.

By the ſame expedient to which I have thus been obliged to have recourſe for procuring to the porcelain clay of Cornwall the ſtandard degree of diminution, and reſiſtence to fire, the ſame qualities may probably be communicated to any other clay that is tolerably pure from calcareous earth and iron; ſo that the thermometer clay is no longer to be conſidered as the produce of any particular ſpot (which was the principal incon-

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venience originally imagined to attend it), but may be procured and prepared in all parts of the world where good common clay, and alum, are to be found; and *correſponding* thermometers may, conſequently, be conſtructed, without any ſtandard to copy from. For, if a converging canal be formed, of any convenient length, with the widths at the two ends in the proportion of 5 to 3, with the ſides perfectly ſtraight, and divided into 240 equal parts, numbering the diviſions from the wider end*;—and if a clay be obtained of ſuch quality, that when formed, in the manner already mentioned, into pieces of ſuch ſize as to enter to 0 in the gage or canal, theſe pieces ſhall juſt begin to diminiſh, or go a little further in the canal, by a heat viſibly red;—go to 27, by the heat in which copper melts;— about 90 by the welding heat of iron; about 160, by the greateſt heat that can be produced with coaked pit-coal in a well conſtructed common air-furnace, about eight inches ſquare, ſtill continuing bibulous, ſo as to ſtick to the tongue: ſuch gages, and pieces of ſuch clay, ſo adjuſted, will always compoſe correſpondent thermometers.

Having mentioned occaſionally ſeveral alternate periods of dilatation and contraction in clay, it may be proper to ſtate, and bring into one view, the whole ſucceſſion of changes which I have obſerved in this curious material; as otherwiſe they might create ſome confuſion in the minds of thoſe who have not had occaſion to think attentively on this ſubject, and lead them to aſk how a body ſo variable, and liable to ſuch oppoſite changes from different degrees of heat, can yet be a juſt meaſure of thoſe degrees.

* Or the diviſions on the ſide may be continued to 300; and in that caſe, inſtead of the widths of the two ends being in proportion of the odd numbers 5 and 3, the one will be juſt double to the other.

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The changes which take place in all the natural clays that have come under my examination are ſix.

1. The firſt is, the *ſhrinking* of the moiſt clay in drying, from the mere loſs of its water. The purer the clay is, the more water it requires to ſoften it, and the more it diminiſhes in bulk by the loſs of that water.

2. The dry clay, gradually heated, preſerves its bulk unvaried up to the approach of ignition. At this period it is *enlarged* a little; probably, as already obſerved, from its combined air endeavouring to eſcape.

3. When this air has made its eſcape, the clay begins to diminiſh, or to *loſe the bulk it had before acquired*; and returns back, ſooner or later, to the ſame dimenſions which it was of when dry. It is at this point that the thermometric diminution commences.

4. From this point the clay continues to *diminiſh* more and more in proportion as the heat is increaſed. This I call the *thermometric ſtage* of diminution: it is of greater or leſs extent, terminating at different periods of heat, according to the nature of the clay: in the ſtandard thermometer clay, it commences with viſible ignition, and continues to (doubtleſs far beyond) the extreme heats of our furnaces, an interval conſiſting of 160 degrees of the ſcale: in others, it begins 4, 6, and in ſome even 15 of thoſe degrees later, and terminates alſo much ſooner: and in ſome its whole extent is not above 20 of the ſame degrees. Throughout the greateſt part of this ſtage, the clays are found to retain their property of ſticking to the tongue and imbibing water: between this *bibulous* ſtate and the *vitreſcent* there is an intermediate one, diſtinguiſhed by the name of *porcelain*; and to the higher term of this porcelain ſtate the ſtage of thermometric diminution ſeems to continue.

 5. When

5. When the clay has paſſed the porcelain ſtate, it begins to be *enlarged* again, a ſymptom of the vitreſcent ſtage being commenced; and in this period it ſwells more or leſs, according to the nature of its compoſition.

6. By further heat the ſwelled maſs, becoming fluid, ſubſides, is converted into glaſs or ſlag, and *contracted into leſs volume* than the clay occupied in any of its preceding ſtates.

It is plain, therefore, that clay can be a meaſure of heat no further than from ignition, or that point beyond ignition where the third ſtage terminates, to the beginning of the vitreſcent ſtage; and that, as the three firſt changes are completely paſſed before the clay is applied to thermometric purpoſes, being ſtrictly no other than preparatory proceſſes, the thermometer-pieces, whatever *clay* they may be made of (provided it is ſufficiently unvitreſcible), are to be conſidered as poſſeſſing only the fourth ſtage. But a ſingular property of the *compoſition* of clay and alum earth remains to be mentioned, *viz.* that it has really no other than this one ſtage: it ſuffers no enlargement of its bulk at ignition, or in any other period; but proceeds in one uninterrupted courſe of diminution, from the ſoft ſtate in which the pieces are formed, up to the extreme fires of our furnaces. Though the diminution, however, is uninterrupted, it is at the ſame time ſo inconſiderable at the beginning, from the heat of boiling water (at which the pieces are adjuſted) up to ignition, that the ſame point of viſible redneſs is taken for the commencement of the ſcale, in this as in the original clay, without any ſenſible error or variation in their progreſs.

I am inclined to believe, though experiments have not yet enabled me to ſpeak with certainty on this point, that the ſame cauſe which enlarges the *natural clays* on their firſt expoſure to the fire, operates alſo in this *compoſition*, but in a much lower degree;

degree; that while the natural *clays* have their whole maſs diſtended by the efforts of the air in forcing its paſſage, the *compoſition* is only reſtrained in its diminution, or prevented from diminiſhing ſo faſt as it otherwiſe would do, and as it is found to do in the ſubſequent part of its courſe, after the air has eſcaped from it.

As the compoſition of clay and alum earth is far more tenacious of water than the clay itſelf, and was found, after being dried by the heat of boiling water, to yield, by diſtillation in a retort, above three times as much aqueous fluid as the original thermometric clay did; it ſeems probable, that a part of this water, retained to the approach of ignition, and in a ſtate of chemical combination, may facilitate the paſſage of the air, ſerving as a vehicle to convey it off through interſtices not permeable to air alone, and conſequently enabling it to eſcape without doing that violence to the maſs, which the natural clays ſuſtain from the expulſion of their air after the water has been detached from it; for the experiments of Dr. PRIESTLEY have ſhewn, that veſſels even of burnt clay are permeable to air when they have imbibed water into their ſubſtance, though not at all ſo in a dry ſtate.

I have now communicated the reſult of a ſeries of experiments which have taken conſiderable time, attention, and labour to complete. Whether the importance of the object will juſtify me in troubling this illuſtrious Society with ſo minute a detail of the moſt material operations, and their reſults, is not for me to determine. If the thermometer ſhould not yet be brought to the perfection that may be wiſhed, I flatter myſelf that ſome abler hand may now take up the ſubject to more advantage; and that philoſophers and artiſts will

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not be leſs ſucceſsful in ſupplying what may ſtill be deficient, and in aſcertaining, by the *contraction of argillaceous matter*, the meaſurements and effects of the various degrees through the immenſe extent of luminous fire, than they have been with reſpect to the limited and narrow compaſs of low heat, which is meaſurable by the *expanſion of fluids*.

Fig. 4.

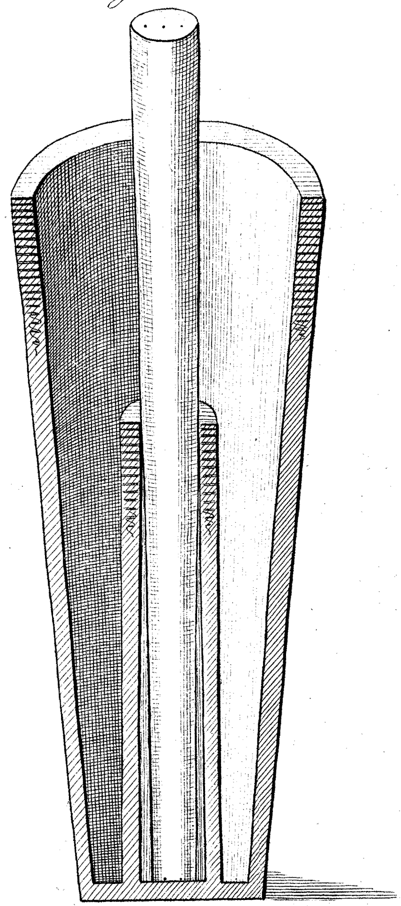


Fig. 1.

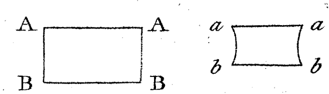



Fig. 2.

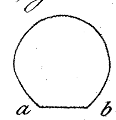
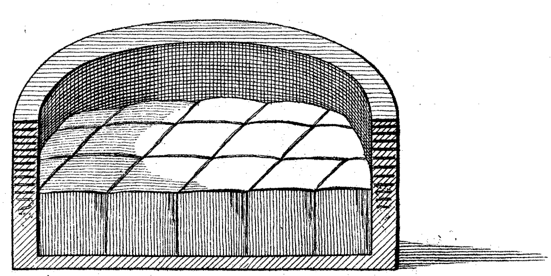



Fig. 3.



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